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**COMPARATIVE NIGHT VISION GOGGLE VISUAL  
ACUITY MEASUREMENTS PERFORMED IN THE  
A-10 AIRCRAFT IN AN OPERATIONAL SETTING**

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## PREFACE

This work was conducted at Nellis AFB, NV, by the Armstrong Laboratory, Aircrew Training Research Division (AL/HRA), with support from the University of Dayton Research Institute (UDRI). Both are located at Williams AFB, AZ. AL/HRA conducts visual training effectiveness research in support of aircrew training technology. One entity of this effort is a night vision training research program. UDRI, working under Contract F33615-90-C-0005, supports AL/HRA by supplying night vision device (NVD) subject matter expertise in the areas of NVD research, development, test and evaluation.

This report contains comparative data on four different night vision goggles (NVGs) obtained both in laboratory and operational conditions and comparative data on the effect the transmissive characteristics of two different windscreens has on NVG image quality. Work was conducted under Work Unit 1123-32-06, Night Vision Device Training Research, by Dr. Carita A. DeVilbiss, Principal Investigator. The laboratory contract monitor was Ms Patricia A. Spears and the effort was managed under Work Unit 1123-03-85, Flying Training Research Support.

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## COMPARATIVE NIGHT VISION GOGGLE VISUAL ACUITY MEASUREMENTS PERFORMED IN THE A-10 AIRCRAFT IN AN OPERATIONAL SETTING

### INTRODUCTION

Night vision goggles (NVGs) have been employed in rotor wing aircraft for over twenty years, but only recently has employment in fixed wing fast movers begun. NVGs operate by intensifying available radiance in the electromagnetic spectrum ranging from the far visible to the near infrared. Their use has greatly increased night operational capability by significantly improving night visual performance over the human eye's unaided scotopic potential.

The 422nd Test and Evaluation Squadron (TES), Air Combat Command, Nellis AFB, Nevada, requested assistance from the Night Vision Programs Office (NVPO) of the Air Force Armstrong Laboratory, Aircrew Training Research Division (AL/HRA) which is located at Williams AFB, Arizona. The following were included in the evaluation: (1) determine the operational utility of NVGs in the A-10 aircraft, (2) evaluate the lighting modification for NVG compatibility, (3) evaluate NVG-compatible, ground marking devices for the close air support mission, (4) evaluate a new windscreen's effects on NVG performance, and (5) conduct an operational comparison of four different NVGs. The scope of NVPO's assistance was to provide objective performance data for the four NVGs which were to be evaluated, provide objective data comparing the two different windscreens, and determine the effect of various cockpit transparencies on NVG performance.

### METHOD

#### Settings

#### Test Lane

To obtain laboratory quality data from the test pilots, an NVG test lane was constructed at the 422nd TES facility. The test lane consisted of a blacked-out room, an illumination source, and targets for adjusting and focusing the NVGs. An observer would sit 20 feet from the test target and interpret all four chart orientations. The illuminator was calibrated to produce both quarter moon and mean starlight illumination conditions. Data in the form of visual acuity (VA) measurements were collected with each pilot viewing high-, medium-, and low-contrast targets under each lighting condition.

## Hangar

To provide a static real-world environment with the test pilots and the actual aircraft, visual acuity data were collected with the pilot seated in the cockpit of one of the A-10 test aircraft. The aircraft was completely enclosed in a light-tight hangar (Fig. 1). Additionally, all data were collected at night to further ensure adequate lighting control.

## Apparatus

### Night Vision Goggles

Four production quality night vision goggles were used in this evaluation.

F4949 ANVIS ("Super" ANVIS). One model of the new F4949 goggle (s/n 0000), which incorporates an improved image intensification tube, was used in this evaluation. This NVG is a direct view design based on the standard ANVIS goggle. Design changes have been incorporated for adaptation to the fixed wing fast mover aircraft/mission.

CATS EYES. One CATS EYES Mk IV (s/n SE 0005) was used in the evaluation. This NVG is an indirect view design incorporating a combiner in which the pilot views the intensified image. The image intensification tube is located above the pilot's line of sight. It is currently the standard goggle for US Navy/US Marine Corps (USN/USMC) fixed wing aircraft.

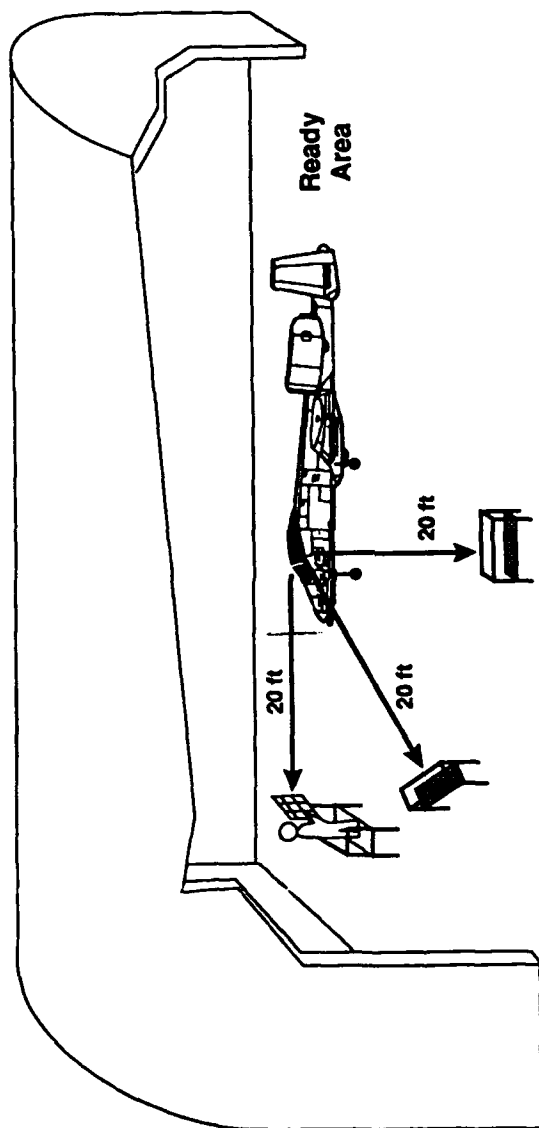
NITE OP. One NITE OP goggle (s/n 61) was used in the evaluation. This NVG is a direct view design that is similar to ANVIS but designed to meet the mission requirements of the Royal Air Force and the Royal Navy.

EAGLE EYE. Three EAGLE EYE goggles (s/n 07, 013, and 014) were used at various portions of the evaluation. During the early phase of testing, #07 was removed from the evaluation at the manufacturer's request. EAGLE EYE #013 developed a tube problem during the evaluation and was replaced by #014 which was used for the remainder of the performance measurements. This NVG, like CATS EYES, is an indirect view design incorporating a combiner. However, in this design the intensification tube is located laterally relative to each eye.

### Aircraft

A-10 #171 and A-10 #172 were the test aircraft for this project. A special modification to the cockpit lighting system was installed by Grumman Aerospace Corporation to provide NVG-compatible cockpit lighting. A cockpit lighting evaluation was conducted by personnel from the Naval Air Warfare Center, Aircraft Division, NAS Patuxent River, MD.





**Figure 1**  
Hangar Layout. Approximate layout of A-10 aircraft within hangar and measurement positions. Ready area located at the rear of the aircraft and on opposite side from measurement.

A new "water white" windscreen was authorized for each test aircraft to improve transmissivity of near infrared energy for which the goggles have maximum sensitivity. At the time of this ground test, the new windscreen had been installed in only one of the test aircraft, A-10 #171. The majority of the VA data were obtained with #171. Aircraft #172 was used on the final night while the pilots completed subjective cockpit compatibility evaluations with the goggles. This provided an opportunity to obtain one set of performance data through the old windscreen for comparative purposes.

### Target

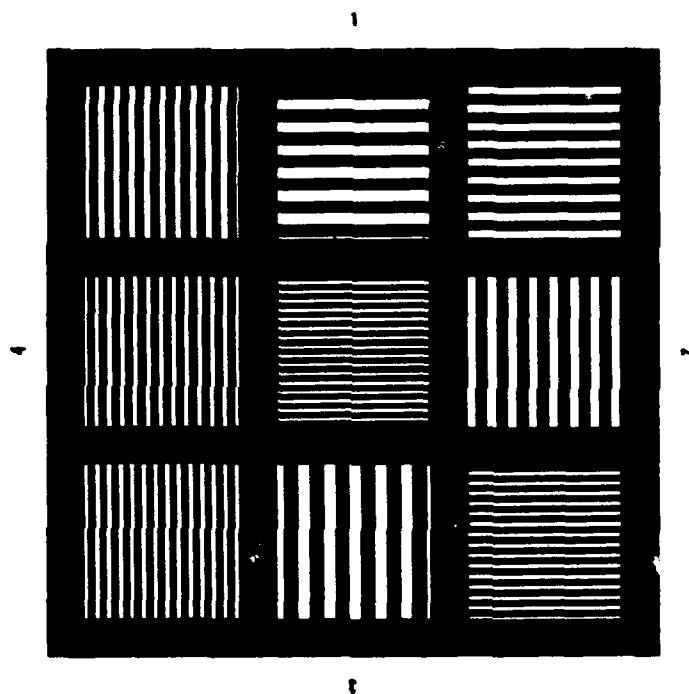
The test targets used were NVG resolution charts designed by Armstrong Laboratory's Visual Display Systems Branch at Wright-Patterson AFB, OH. Each chart includes nine square-wave grating patterns arranged in three rows and three columns (Fig. 2). The target provides four unique arrangements of the grating patterns depending upon which side of the target is located at the top. The charts are available in three different contrast levels. The high-contrast chart (95%) provides sharp black-and-white bars and is used as the standard chart for NVG preflight with equivalent Snellen acuity levels ranging from 20/35 to 20/100. Medium- and low-contrast charts (50% and 20% respectively) of the standard chart are also available. All three types were used to measure VA levels under the two different illumination conditions. Additionally, a newer and higher resolution version of the 95% contrast chart was used to obtain equivalent Snellen acuities ranging from 20/20 to 20/60.

### Illumination Sources

To be able to see the NVG test targets, the targets must be properly illuminated. Two different NVG target illuminators were used during testing.

Illuminator 1. This illuminator was designed to produce the same relative response as a standard 2856 K blackbody source over the sensitivity range of Gen III image intensification tubes (Fig. 3). Approximate half-moon, quarter-moon, and starlight conditions are achieved by proportionally decreasing the amount of light emitted from the source. There is, however, no alteration of the spectral distribution of the energy. The night illuminator was produced by Armstrong Laboratory's Visual Display Systems Branch at Wright-Patterson AFB, OH.

Illuminator 2. This illumination source was a Hoffman Engineering LS-65C Luminance Standard, supplied and operated by the NAS Patuxent River personnel. It is designed to reproduce the spectral distribution of the night sky. The illuminator was



**Figure 2**  
Standard NVG Visual Acuity Resolution Chart  
Developed at Visual Displays Branch,  
Armstrong Laboratory, Wright-Patterson AFB, OH

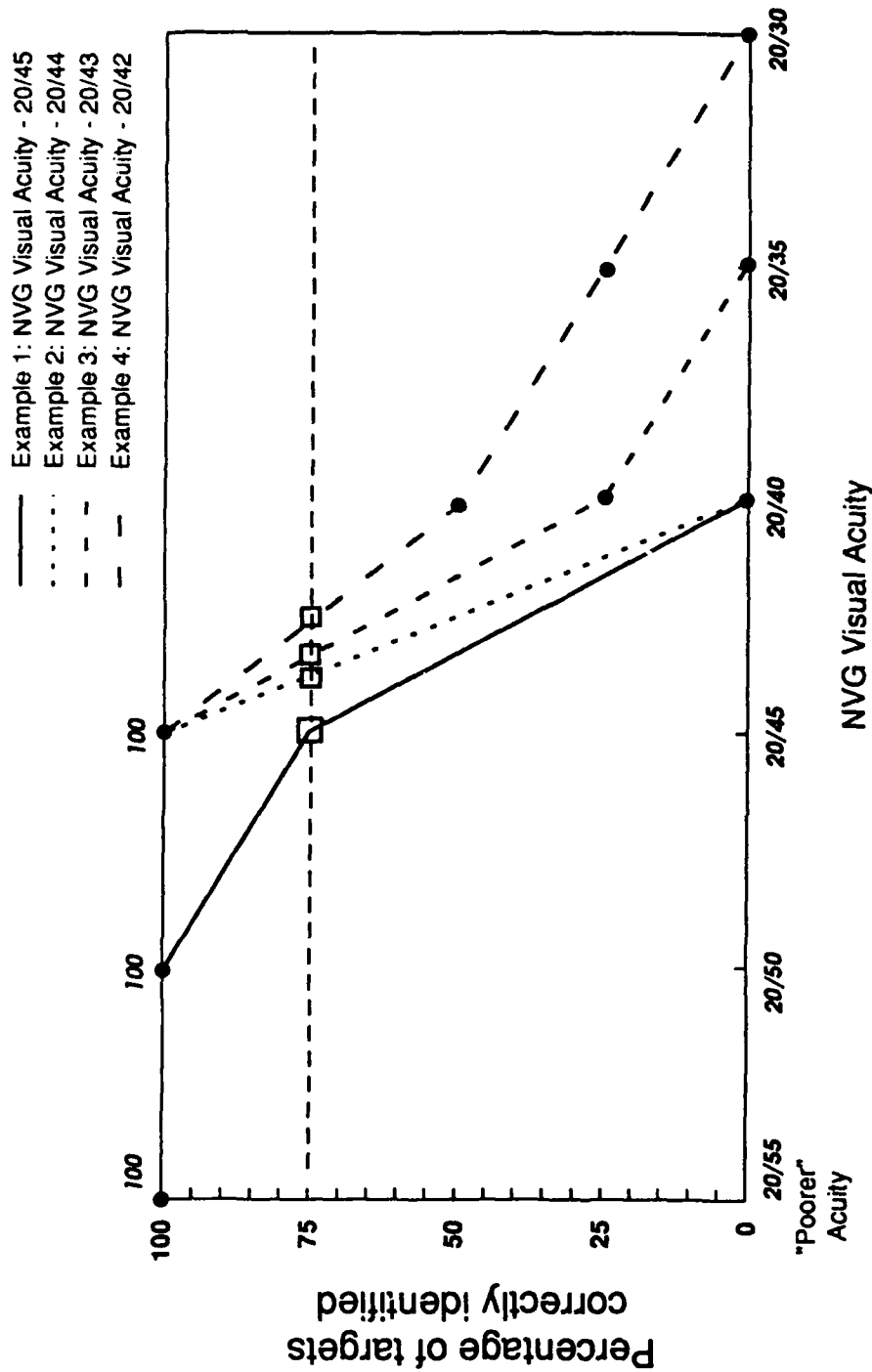


Figure 3  
 Night Illuminator Response. Illustration of the impact of employing the  
 "75% Strategy" for determination of NVG visual acuity values between  
 the levels on the resolution chart, which are at 5-ft increments

adjusted to produce  $1.7E^{-10}$  radiance on the white portion of the target (per MIL-L-85762A) to approximate mean starlight.

#### Photometer

The instrument used to measure the lighting conditions was a Photo Research Radiometer/Photometer (PR-1530AR) equipped with both Class A and B filters which conform to the relative response curves in MIL-L-85762 (the standard for filters in production NVGs). Measurements of the night illuminator's output as determined during testing in the hangar were as follows:

<u>Filter</u>	<u>Measurement</u>
Photopic	$8.5 \times 10^{-4}$ footLamberts
Scotopic	$11.7 \times 10^{-4}$ footLamberts
Class A	$2.6 \times 10^{-9}$ NR <sub>1</sub> NVIS radiance
Class B	$2.4 \times 10^{-9}$ NR <sub>2</sub> NVIS radiance

### **EXPERIMENTAL DESIGN**

#### Experiment One

To provide objective performance data for the four NVGs being evaluated in the A-10 flight test, NVPO personnel spent a week at Nellis AFB, NV. VA measurements were used to assess and compare goggle performance.

#### Subjects

The six A-10 test pilots who would be conducting the flight test participated as subjects for Experiment One. All but one pilot had at least 20/20 vision in both eyes. The one exception wore spectacles that corrected his vision to 20/20. With the following exceptions, all pilots participated in all data collection sessions. One goggle, EAGLE EYE, was not able to be fitted to one pilot because of his spectacles. Another pilot was unavailable to participate in one session.

#### Measurement Technique

The same technique was used to obtain each NVG VA measurement. The test target was presented 20 feet from the subject in a randomly selected orientation. The observer "read" the target from left to right, top to bottom, by stating the direction of the bars in each pattern (i.e., "horizontal," "vertical," or "blank" if the direction was unclear). After the observer had responded to all nine patterns, the orientation of the target was changed and the process repeated. Four presentations (one for each orientation)

were used for each measurement. Therefore, each individual grating pattern was "read" four times--twice when it was horizontal and twice when it was vertical.

### Dependent Variable

The dependent measure used in the analyses was VA levels calculated from this procedure. NVG acuity was defined as the highest acuity level at which the observer correctly identified at least 75% of the presentations of each grating pattern. Specifically, the acuity level was the denominator of the associated Snellen acuity fraction (e.g., 45 for 20/45) at which the pilot correctly identified at least three out of four gratings of a given size.

### Procedure

Representatives from each vendor were present on the first day to instruct the test pilots and life support personnel on the proper mounting procedures for their goggles. Additionally, NVG subject matter experts from NVPO gave instructions on proper adjustment procedures for each goggle. Prior to each measurement session, the pilot donned the assigned NVG and performed the proper adjustment procedures. Each pilot participated in four data collection sessions with each of the four goggles.

Session 1: Test Lane. During this session, six VA measurements were obtained under laboratory conditions in an approved NVG test lane using the HIGH, MED, and LOW contrast targets under both quarter-moon and starlight illumination conditions.

Session 2: New Windscreen--Cockpit Lights OFF. These sessions were conducted at night with the pilots seated in Aircraft #171 which was placed in a darkened hangar. With all of the cockpit lights OFF, five VA measurements were obtained for each pilot with each goggle. The first measurement obtained was a baseline value with the pilot having an unobstructed view of the test target, i.e., looking over the windscreen. The other four measurements were obtained as the pilot viewed the test target through various transparencies, i.e., (1) the windscreen alone, (2) the heads-up-display (HUD)/windscreen combination, (3) the quarter panel, and (4) the canopy.

Session 3: New Windscreen--Cockpit Lights ON. These sessions were conducted with Aircraft #171 under the same conditions with one exception: the cockpit lights were turned ON. Since a baseline (unobstructed) value had already been established, only the other four VA measurements were obtained.

Session 4: Old Windscreen--Cockpit Lights ON. These sessions were conducted on the final night with Aircraft #172, which still had the old windscreen. Due to time constraints, only the "through the windscreen" acuity measurement was obtained for each pilot with each goggle.

### Independent Variables

The complete data set provided the four comparisons described below. One independent measure, GOGGLE (F4949 ANVIS, CATS EYES, NITE OP, or EAGLE EYE), was common across all comparisons. Each individual comparison required specific additional independent measures.

Contrast and Lighting. Since various goggle types are known to degrade at different rates as illumination conditions are reduced, data were obtained to form a comparison of that effect on the test GOGGLES. Session 1 data provided for a comparison between CONTRAST level (high, medium, or low) and LIGHT level (quarter moon or starlight).

Baseline. Data obtained in the test lane were laboratory quality data, whereas data obtained in the hangar were gathered in a static real-world environment. Since the data were obtained in two different SETTINGS (test lane or hangar), a comparison was made to ensure a bias was not introduced. Data obtained during Session 1 for each goggle with the high contrast target were compared with the unobstructed data obtained during Session 2 (obtained using the same chart). The same illuminator was used for each session and was set at the same illumination level (quarter moon).

Transparencies. Data obtained during Sessions 2 and 3 provided a comparison between GOGGLE performance through various TRANSPARENCIES (i.e., windscreen alone, HUD/windscreen combination, quarter panel, and canopy) and cockpit LIGHT (ON or OFF). The same quarter-moon illumination source was used for all measurements.

Windscreen. To provide comparison between GOGGLE and WINDSCREEN (new or old), the data obtained during Session 3 (new windscreen) were compared with the data obtained in Session 4 (old windscreen). The cockpit lights were ON during both of these sessions.

### Analysis

For each of the comparisons, a between-subjects analysis of variance (ANOVA) procedure was used for each analysis. The SAS General Linear Models procedure was used for all analyses since it compensates for unbalanced design. The data were unbalanced because only five of the six pilots were able to be fitted with one of the goggles.

## Experiment Two

The result of the windscreen comparison obtained in Experiment One (that there was no significant difference between the old and new windscreen) strongly contradicted expected results based on observed differences during actual daytime and nighttime flights. Therefore, the windscreen evaluation was repeated to more accurately assess the impact on NVG performance.

### Light Levels

The first evaluation was conducted under the relatively high illumination level of quarter moon using Illuminator 1. Due to the various performance characteristics of NVGs (such as automatic gain control), a lower illumination level would be a more appropriate level at which to obtain an accurate comparative assessment. Therefore, additional VA data were collected under starlight conditions using Illuminator 2.

### Subjects

Two experienced NVG aviators were used to collect performance data with three of the same goggles (F4949 ANVIS, CATS EYES, and NITE OP) used in the first evaluation.

### Procedure

The same experimental setup was employed for this data collection (with the exception of the illumination level). All cockpit lights were off during data collection.

### Independent Variables

Three independent variables were included. There were three levels of the first variable, GOGGLE (i.e., F4949 ANVIS, CATS EYES, and NITE OP) and the second variable, WINDSCREEN, had two levels (old or new). The third independent variable, VIEW, represented the three conditions under which measurements were obtained (i.e., unobstructed view over the windscreen, view through the windscreen, and view through the HUD-windscreen combination).

### Analysis

A balanced three-factor within-subjects ANOVA with VA as the dependent measure was used to analyze the data obtained from these measurements.



## RESULTS

### Experiment One

#### Contrast and Lighting

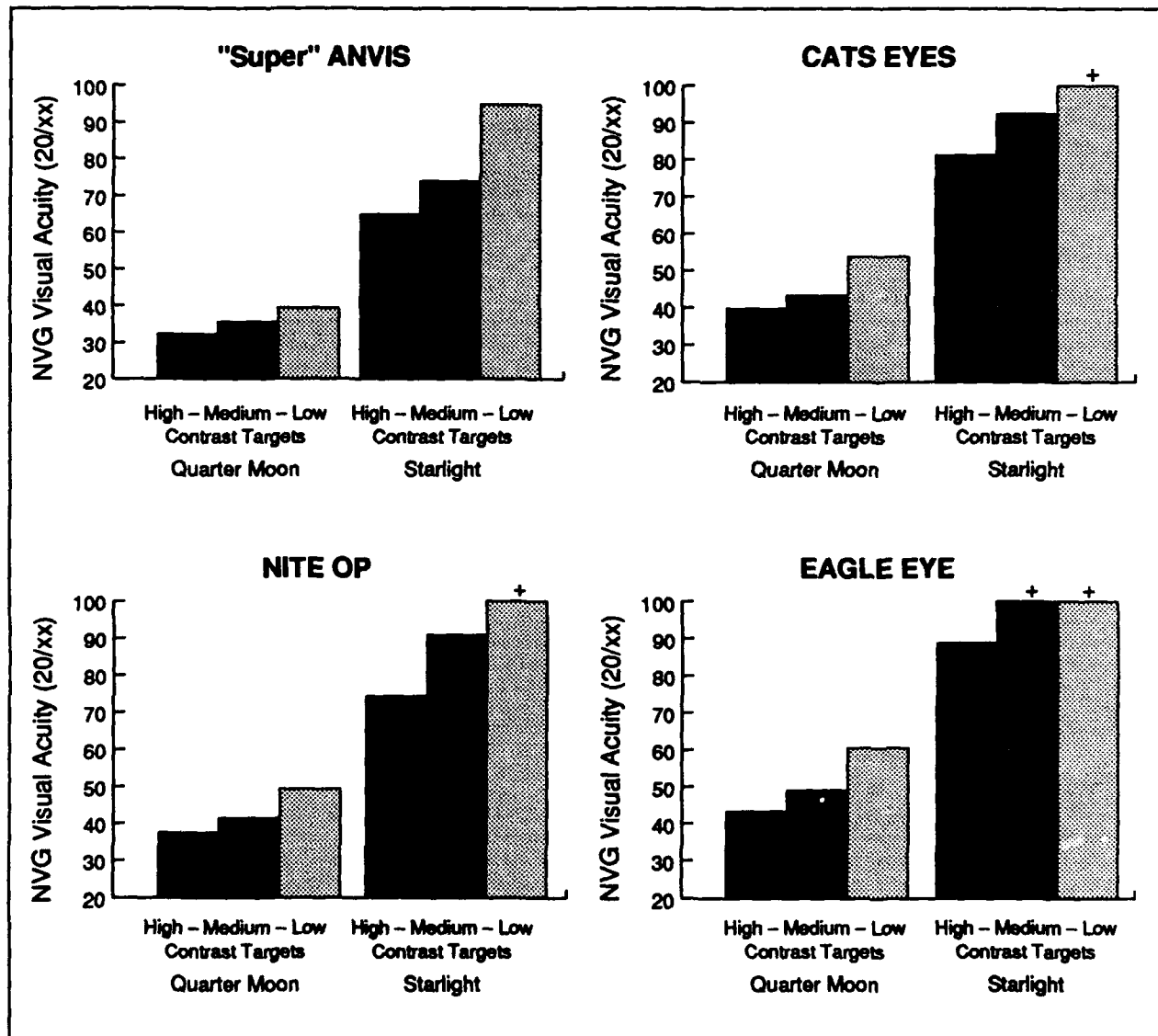
An ANOVA procedure was not accomplished on this data set because of truncation. The poorest acuity which could be measured with the targets used in this experiment was 20/100. Under starlight illumination, one-third of the measurements (22 of 69) indicated the acuity level was worse than 20/100. A summary of impact of decreasing contrast (95% down to 20%) and decreasing illumination on goggle performance is provided as Figure 4.

#### Baseline

Table 1 presents the results of an unbalanced ANOVA which compared goggle performance obtained under laboratory conditions (i.e., in the test lane) and performance obtained in a static real-world environment (i.e., in the hangar). Of the 48 possible measurements, two were lost because EAGLE EYE could not be fitted for one pilot. There was no significant difference which could be attributed to the setting in which the measurement was obtained. There was a significant difference between goggles ( $F_{(3,38)} = 23.24$ ,  $p < 0.001$ ). The F4949 ANVIS performed significantly better than the other goggles (Fig. 5a). EAGLE EYE performed significantly worse than the other three, and the remaining two, CATS EYES and NITE OP, did not significantly differ from one another.

#### Transparencies

Table 2 presents the results of an unbalanced ANOVA which compared goggle performance through various aircraft transparencies. Of the 192 possible measurements, eight were lost because EAGLE EYE could not be fitted for one pilot. For quarter-moon illumination, there were no significant differences between the acuities obtained through the four aircraft transparencies. Additionally, there were no significant differences which could be attributed to whether the cockpit lights were turned ON or OFF. However, there was a significant difference between goggles ( $F_{(3,152)} = 87.03$ ,  $p < 0.001$ ). The F4949 ANVIS performed significantly better than the others (Fig. 5b). EAGLE EYE performed significantly worse than the other three, and the remaining two, CATS EYES and NITE OP, did not significantly differ from one another.



**Figure 4**  
**Contrast and Lighting Results.** Average goggle performance obtained in the Test Lane with three targets (high, medium, and low contrast) at two illumination levels (quarter moon and starlight). The "+" at the top of a bar indicates the average goggle performance for condition was poorer than 20/100, the measurement limit.

**Table 1. Baseline ANOVA Table.** Sources of variance computed in the analysis of variance to evaluate difference in baseline acuity levels under quarter-moon conditions which were obtained in two settings (Test Lane and Hangar) for each of the four goggles ("Super" ANVIS, CATS EYES, NITE OP, and EAGLE EYE).

<u>Source</u>	<u>Degrees of freedom</u>	<u>Sum of squares</u>	<u>F value</u>	<u>Pr &gt; F</u>
GOGGLE	3	1030.32	23.24	<0.001
SETTING	1	11.50	0.78	0.383
GOGGLE*SETTING	3	59.23	1.34	0.277
ERROR	3	8561.67		

**Table 2. Transparencies ANOVA Table.** Sources of variance computed in the analysis of variance to evaluate difference in acuity levels under quarter-moon conditions which were obtained by viewing the target through four different aircraft transparencies (windscreen alone, HUD-windscreen combination, quarter panel, and canopy) with the cockpit lights on and turned off.

<u>Source</u>	<u>Degrees of freedom</u>	<u>Sum of squares</u>	<u>F value</u>	<u>Pr &gt; F</u>
GOGGLE	3	6498.75	87.03	<0.001
TRANS	3	64.02	0.86	0.465
GOGGLE*TRANS	9	56.23	0.25	0.986
LIGHT	1	13.01	0.52	0.471
GOGGLE*LIGHT	3	107.59	1.44	0.233
TRANS*LIGHT	3	29.26	0.39	0.759
GOGGLE*TRANS*LIGHT	9	17.22	0.08	0.999
ERROR	152	3783.33		

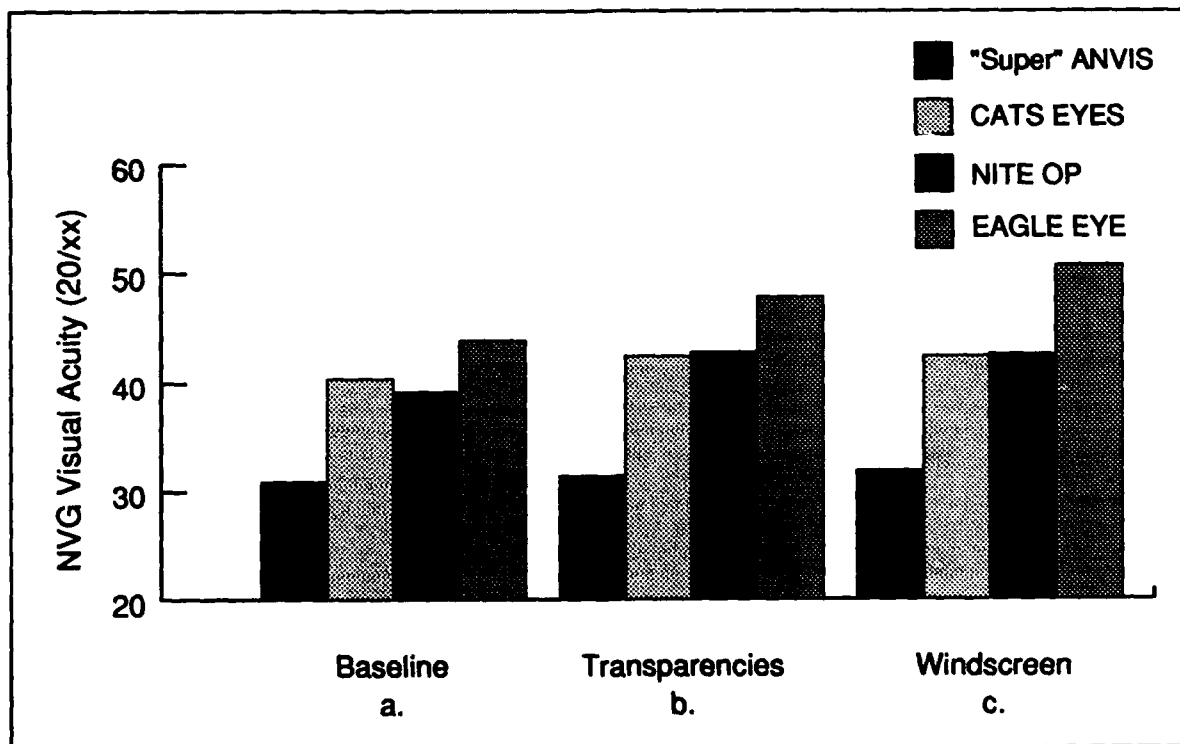
### Windscreen

Table 3 presents the results of an unbalanced ANOVA of goggle performance viewing through the old and new windscreens. Due to the missing values previously discussed, only 42 of the possible 48 observations could be used in this analysis. Under quarter-moon illumination conditions, there were no significant differences which could be attributed to the windscreen. There was a significant difference between goggles ( $F_{(3,34)} = 13.73$ ,  $p < 0.001$ ) which can be seen in Figure 5c. As with the previous two analyses, F4949 ANVIS performed significantly better, there was no

significant difference between CATS EYES and NITE OP, and EAGLE EYE performed significantly worse.

**Table 3. Windscreen ANOVA Table (Exp. 1).** Sources of variance computed in the analysis of variance to evaluate difference in acuity levels under quarter-moon conditions which were obtained by viewing the target through an old and new aircraft windscreen.

<u>Source</u>	<u>Degrees of freedom</u>	<u>Sum of squares</u>	<u>F value</u>	<u>Pr &gt; F</u>
GOGGLE	3	1782.16	13.73	<0.001
WINDSCREEN	1	5.24	0.12	0.730
GOGGLE*WINDSCREEN	3	12.05	0.09	0.964
ERROR	34	1471.52		



**Figure 5**

Goggle Results. Average NVG visual acuity obtained by each of the four goggles in the three analyses of variances (baseline, transparencies, and windscreen). In all three analyses "Super" ANVIS produced the best performance and EAGLE EYE performed significantly worse. CATS EYES and NITE OP were not significantly different from one another.

## Subjects

In all three of the analyses presented, the only significant difference was attributed to which goggle was used. To describe how individual goggle performance varied across the six test pilots, the total measurement range (from best to worst VA levels) for each pilot is presented as Figure 6. The vertical line on each graph indicates the overall average performance for that goggle. Each pilot's performance can be compared to this overall level. For example, Pilot 6 tended to obtain better than average performance with CATS EYES and NITE OP, but poorer than average performance with F4949 ANVIS and EAGLE EYE.

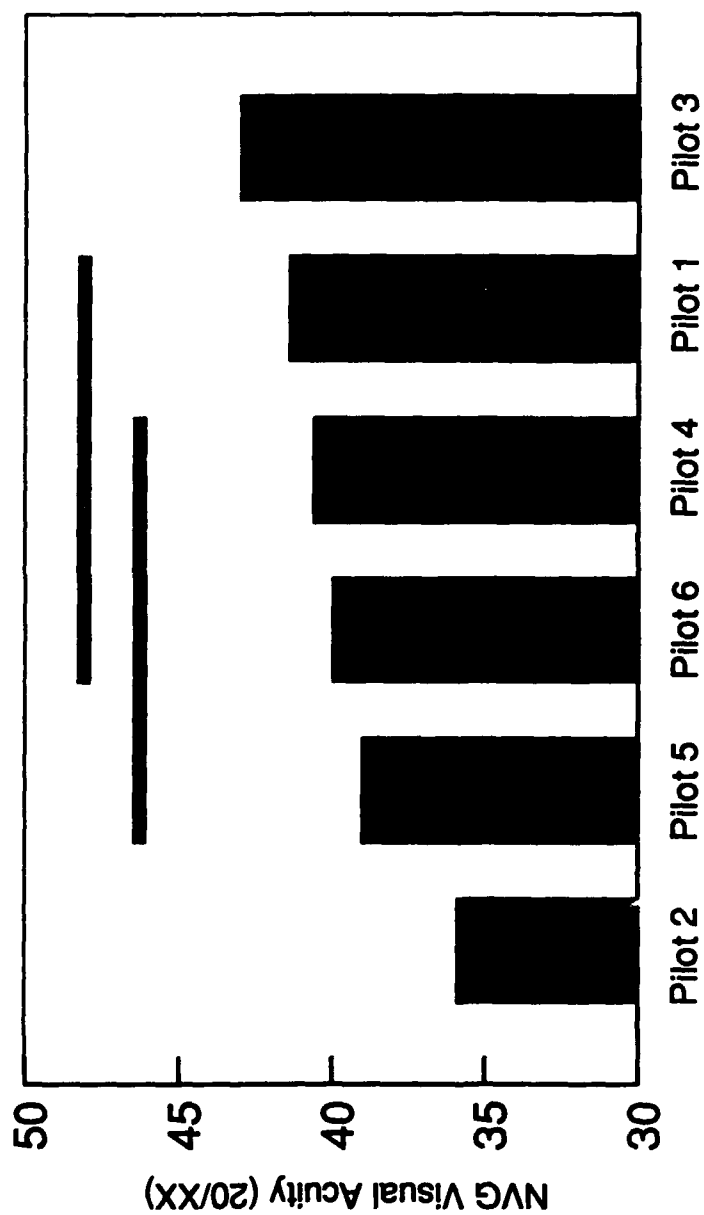
## Experiment Two

### Goggles

The summary ANOVA table for Experiment Two is presented as Table 4. As expected from Experiment One, the performance of the goggles was statistically significant ( $F_{(2,18)} = 68.51$ ,  $p < 0.001$ ). The best overall performance across both windscreen and all transparencies was obtained with F4949 ANVIS (20/58.2). NITE OP performance was next (20/69.4), and CATS EYES was last (20/79.9). Additionally, the performance of each goggle was significantly different from the other.

**Table 4. Windscreen ANOVA Table (Exp. 2).** Sources of variance computed in the analysis of variance to evaluate difference in acuity levels under quarter-moon conditions which were obtained by viewing the target through an old and new aircraft windscreen.

<u>Source</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>F Value</u>	<u>Pr &gt; F</u>
GOGGLE	2	2839.50	68.51	<0.001
WINDSCREEN	1	3441.78	166.09	<0.001
GOGGLE*WINDSCREEN	2	756.06	18.24	<0.001
TRANS	2	4138.17	99.85	<0.001
GOGGLE*TRANS	4	291.83	3.52	0.027
WINDSCREEN*TRANS	2	1112.72	26.85	<0.001
GOGGLE*WINDSCREEN*TRANS	4	305.94	3.69	0.023
ERROR	18	373.00		



**Figure 6**  
Average visual acuity for each pilot across all measurement conditions and all goggles. Horizontal bars indicate groupings within which performances are not statistically different from one another.

### Windscreen

As was predicted from the observed flight performance, a significant difference between windscreen data was determined ( $F_{(1,18)} = 166.09$ ,  $p < 0.001$ ). Overall, across all factors, the new windscreen yielded significantly better acuities (average 20/59.4) than were obtained through the old windscreen (average 20/78.9).

### View

The three views (i.e., unobstructed view over the windscreen, view through the windscreen, and view through the HUD/windscreen combination) were statistically different ( $F_{(2,18)} = 99.85$ ,  $p < 0.001$ ) from each other. The best overall performance (20/54.4) was obtained with the unobstructed view over the windscreen. Goggle performance was significantly degraded when measured through the aircraft windscreen or HUD/windscreen combination (20/73.5 and 20/79.6, respectively). All three averages were significantly different from one another.

### Windscreen \* Goggle Interaction

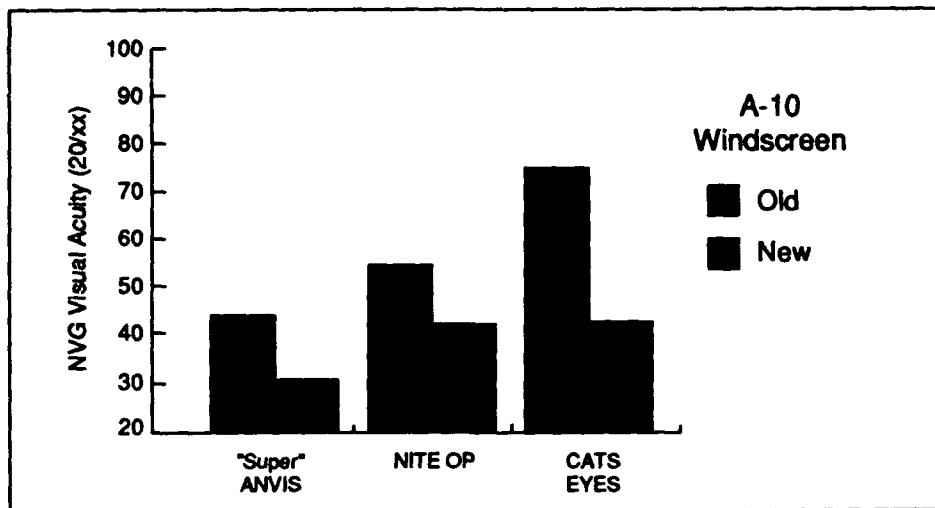
There was a significant two-way interaction between the windscreen and goggle ( $F_{(2,18)} = 18.24$ ,  $p < 0.001$ ). As seen in Figure 7, the relatively poor performance of CATS EYES with the old windscreen was responsible for this significant interaction.

### Windscreen \* View Interaction

There was a significant interaction ( $F_{(2,18)} = 26.85$ ,  $p < 0.001$ ) between windscreen and view. As previously identified with the significant main effect, the inclusion of additional aircraft transparencies (i.e., ranging from unobstructed view to HUD/windscreen combination) degraded goggle performance. However, that degradation was greater (Fig. 8) for the old windscreen.

### Goggle \* View Interaction

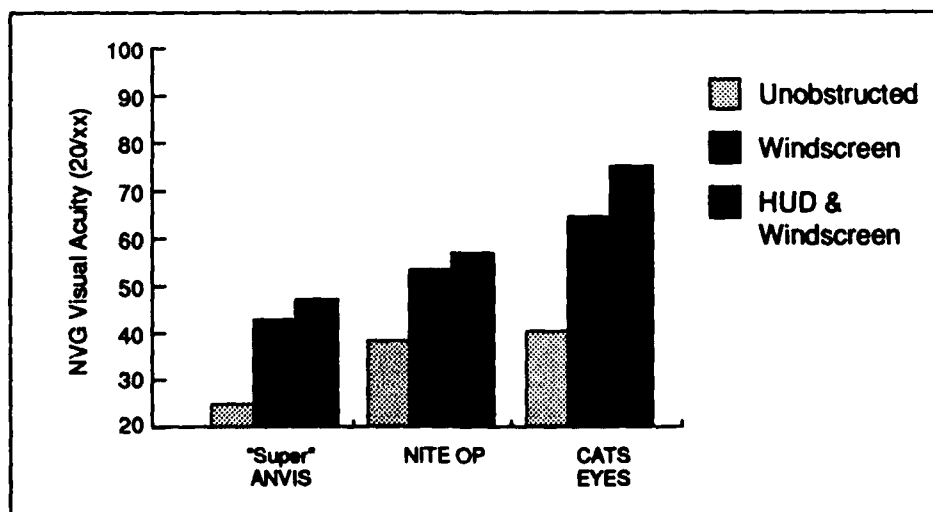
The significant interaction between goggle and view ( $F_{(4,18)} = 3.52$ ,  $p = 0.027$ ) is presented as Figure 9. Again, the degradation across increasing layers of aircraft transparencies is apparent. The source of this significant interaction is that while CATS EYES and NITE OP performed equally in the unobstructed view, CATS EYES were more significantly degraded by the addition of the transparencies.



**Figure 7**  
Windscreen \* Goggle Interaction



**Figure 8**  
Windscreen \* View Interaction



**Figure 9**  
Goggle \* View Interaction



### Windscreen \* Goggle \* View Interaction

The primary result from this analysis is a significant three-way interaction ( $F_{(4,18)} = 3.69$ ,  $p = 0.023$ ) which includes all of the prior results (Fig. 10). Under mean starlight conditions, CATS EYES are severely degraded with the old A-10 windscreen while they are not significantly different from NITE OP with the new windscreen.

## **CONCLUSIONS**

### Comparative Performance

#### Goggles

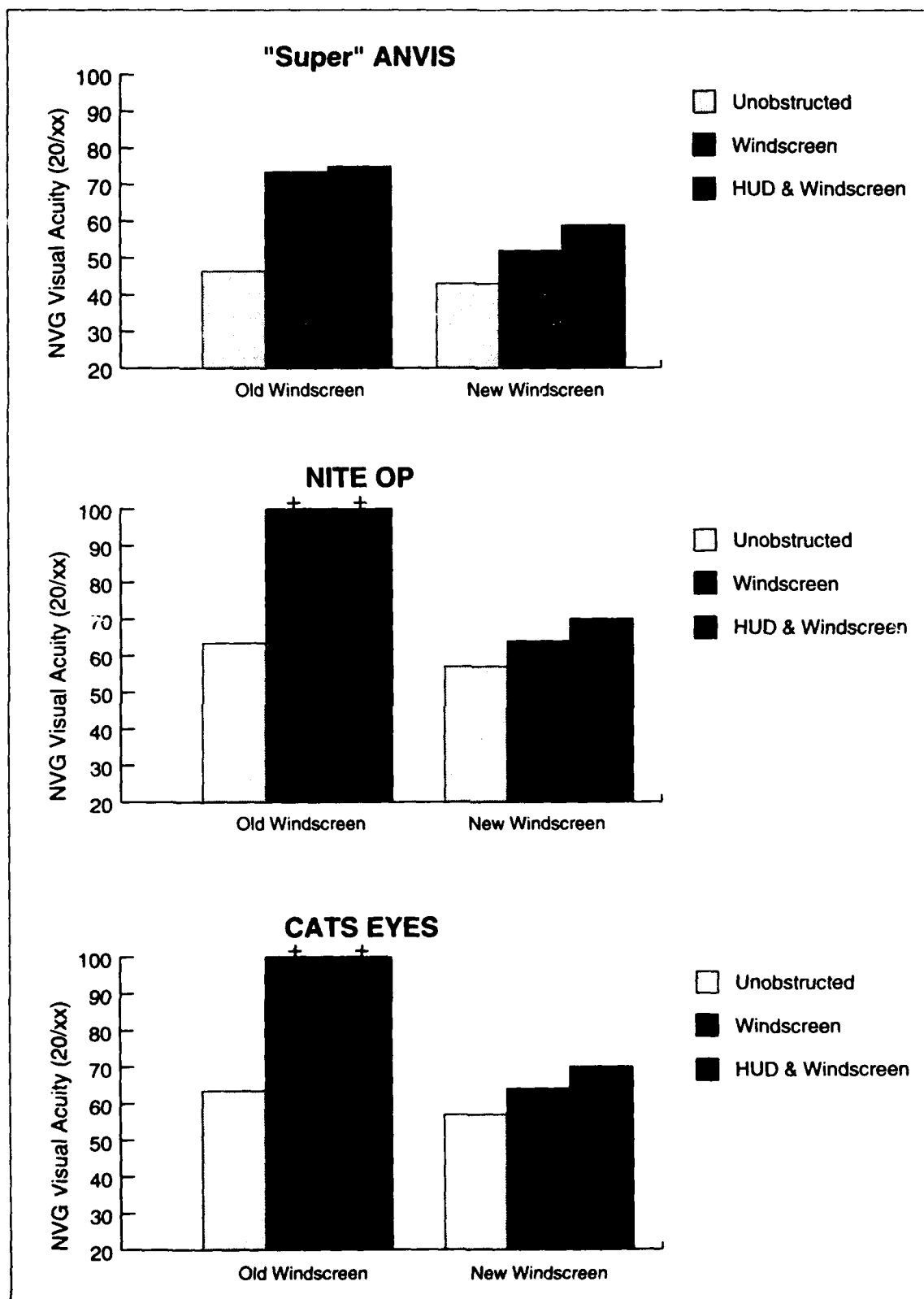
The comparative goggle performance obtained during this evaluation at quarter-moon illumination is summarized in Table 5. The number assigned to each goggle represents the ranking obtained by that goggle, i.e., "1" indicates the best performance and "4" indicates the worst performance.

#### Windscreen

All windscreen measurements taken during Experiment Two are summarized in Table 6. The EAGLE EYE goggle was unavailable for these tests.

#### Overview

The "Super" ANVIS (F4949) outperformed all other night vision goggles in visual acuity measurements under both laboratory conditions and "operational" conditions. However, goggle performance is only one of many factors that must be considered in evaluating their operational utility. The new "water white" windscreen outperformed the old windscreen when comparing NVG visual acuity measurement through each. CATS EYES performance appeared to be degraded the most while viewing through the windscreen under low illumination conditions. This probably is attributable to the increase in system gain necessary in a combiner type design. The consideration is an important one since NVGs, in reality, are used mostly during low illumination conditions.



**Figure 10**  
**Windscreen \* Goggle \* View Interaction**  
 The "+" at the top of a bar indicates the average goggle performance for condition was poorer than 20/100, the measurement limit.

**Table 5. Comparative Goggle Performance.** The number assigned to each goggle represents the ranking obtained by that goggle, i.e., "1" indicates the best performance and "4" indicates the worst performance.

	"Super" ANVIS (F4949)	CATS EYES	NITE OP	EAGLE EYE
Visual acuity measurements:				
1. Across all conditions	1	2	3	4
2. Quarter moon with high contrast target	1	3	2	4
3. Quarter moon with medium contrast target	1	3	2	4
4. Quarter moon with low contrast target	1	3	2	4
5. Starlight with high contrast target	1	3	2	4
6. Starlight with medium contrast target	1	3	2	4
7. Starlight with low contrast target	1	*	*	*
* All performed worse than the lower limit of the resolution charts capability. Hence, no comparative data available.				

### Lessons Learned

The following comments are lessons learned during the evaluation:

1. The procedures used are an effective and simple way to assess NVG performance while viewing through various aircraft transparencies under different illumination conditions.

2. A proper illumination source with correct spectral distribution is critical for accurate NVG performance and transparency transmission assessments.

**Table 6. Windscreen Comparison.** The number assigned to each goggle represents the ranking obtained by that goggle, i.e., "1" indicates the best performance and "4" indicates the worst performance.

	"Super" ANVIS (F4949)	CATS EYES	NITE OP
Visual acuity measurements:			
8. Old windscreen through windscreen alone	1	3	2
9. Old windscreen through HUD/windscreen combination	1	3	2
10. New windscreen through windscreen alone	1	3	2
11. New windscreen through HUD/windscreen combination	1	3	2

3. The use of proper NVG adjustment procedures to maximize the performance of each NVG is essential when comparing performance among different goggles. Each NVG is designed differently and has different adjustment controls, and some NVGs are more difficult to adjust than others.

4. In measuring transparency transmission effects on NVG performance, it is necessary to use an illumination level equivalent to mean starlight to adequately break out individual NVG performance differences.

#### 5. Aircraft lighting.

(a) To help ensure a more accurate "operational" evaluation, prior to taking NVG measurements it is important that all "compatible" lighting and displays be turned on and set at an illumination level equivalent to what would be used during an actual mission.

(b) An indirect method of determining the effectiveness of compatible cockpit lighting is to compare NVG performance with the lighting off to performance with the lighting on.

(c) If the lighting is not NVG compatible, the measurements should be taken with all lighting off. This will not be as accurate an operational assessment as with compatible lighting, but it will help

determine the impact of transparency transmissivities on NVG performance for that particular aircraft.

6. The control of light levels in the aircraft testing area is critical. Consideration should be given to finding a hangar that can be completely closed off and is located in a secluded area removed as much as possible from environmental light sources. If there are ramp lights or other light sources, an effort should be made to have them secured. Finally, the testing should be conducted at night to further reduce the possibility of stray light affecting the results.

7. There was a significant difference between pilots in individual NVG performance which can possibly be attributed to NVG experience. To reduce this effect, it would be best to use subjects that have relatively equal levels of NVG experience.

8. Close coordination is required to ensure aircraft and testing space availability.